way the operations of rat and sparrow clubs and similar bodies. The services of the society will be placed at the disposal of municipalities, boards of health, agricultural societies, shipping and deck companies, and other bodies interested in the suppression of vermin. The society has already received the support of many eminent physicians, bacteriologists and chemists, together with that of agricultural and poultry organizations, public associations and other bodies.

H. B. W.

PLANT CYTOLOGY

Polar Organization of Plant Cells.—Research in plant cytology has resulted in conflicting views as to the extent of such polar organization of plant cells as is well known for certain animals from the work of Rabl, Van Beneden, Flemming and others. Some of the algæ present clear evidence of such polarity, the best known example being Stypocaulon, which has a center in the form of an aster with a centrosome, present at the side of the resting nucleus and dividing previous to each nuclear division, or mitosis, to establish the poles of the spindle. A similar aster is present at the tetraspore mother-cells of Dictyota. Other algæ such as Fucus and Corallina show highly developed centrospheres at the poles of the spindles, but investigations so far indicate that they are formed *de novo* with each mitosis and that there are no permanent centers associated with the resting nuclei to give polarity to the cells.

The research of recent years on the cells (particularly the spore mother-cells) of pteridophytes and spermatophytes has failed to support certain claims for the presence of centrosomes in these groups of plants, and has indicated that their cells are without visible polar organization. As nuclear division approaches in the spore mother-cell fibrillæ appear in the cytoplasm, at first arranged radially, but later becoming associated in cone-shaped groups (constituting the multipolar stage), and at last arranging themselves to form the two opposite poles of the final bipolar spindle. Among the bryophytes, the liverworts have received considerable attention. In this group well-differentiated centrospheres are present at the poles of the spindles, but these are described by all investigators as arising *de novo* and they have not been reported in association with the resting nuclei.

The subject of polar organization in plant cells has received especial attention recently through the work of Harper[1] on the mildews (particularly Phyllactinia), and that of his student Marquette[2] on Isoetes and Marsilia. Harper found in the ascus of Phyllactinia an especially favorable subject for the study of the organization of the resting nucleus and its mitosis in relation to a central body, which is a permanent organ of the cell and gives to the nucleus and cell a definite polar organization. The central body lies on the nuclear membrane and the chromatin elements in an early stage of mitosis have the form of strands, each one attached independently to this center. Even in the resting nucleus, when the chromatin has the structure of a network, its attachment to the central body is evident and indicates that the strands have an individual connection with the central body as a nuclear pole. During the prophase of mitosis the central body divides and the two portions move apart to become the poles of spindle and, at the completion of mitosis, each remains connected with a daughter nucleus, thus maintaining its polarity. Furthermore, in the process of nuclear fusion within the ascus each nucleus contributes its complete polar organization so that the resulting fusion nucleus has for a time two central bodies and two independent groups of chromatic elements, which later gradually fuse into a single system with one central body.

Marquette has discovered a remarkable polarity in the leaf cells of Isoetes. Each resting cell contains a large starch-containing body, which lies so closely pressed against the side of the nucleus that the latter is usually indented. Sometimes the body is present without the starch grains that usually render it very conspicuous. Previous to nuclear division this polar structure elongates and divides by constriction and the two parts draw apart so as to form a furrow on the surface of the nucleus. The separated halves then come to lie at opposite ends of the nucleus, which has become somewhat elongated. These developments take place before the appearance of the chromatin gives

[1] Harper, R. A. Sexual Reproduction and the Organization of the Nucleus in Certain Mildews. *Pub. Car. Inst.*, No. 37, 1905.

[2] Marquette, W. Manifestations of Polarity in Plant Cells which Apparently are without Centrosomes. *Beih. Bot. Centralbl.*, XXI, p. 281, 1907. Concerning the Organization of the Spore Mother-cells of *Marsilia quadrifolia*. *Trans. Wis. Acad. Sci. Art. Let.*, XVI, p. 81, 1908.

indication of the approaching mitosis. As the prophases of mitosis become evident the two polar structures move away from the nuclear membrane, become much flattened, and spindle fibers develop in the region between the two. The polar structures then round up so that in the metaphase of mitosis they are irregularly rounded bodies at the poles of the spindle against which the ends of the spindle fibers press. During anaphase the chromatin of the daughter nuclei comes to lie closely against the surface of the rounded polar structures, and each daughter nucleus when fully formed is deeply indented or kidney-shaped in sections. The amount of starch decreases during the prophases, indicating that there is a consumption of starch at the time of the mitosis. The polar structures increase in size during telophase and remain at the side of the daughter nuclei until the above history is repeated with the next mitosis.

In the spore mother-cells of Marsilia, Marquette has found evidence of polar organization at the time of synapsis. Following the differentiation of the spore mother-cells there is a period of growth during which starch grains appear, first in a scattered arrangement, but soon in a specified region between the nucleus and the wall of the spore case, a situation favorable for an interchange of metabolic movements between the nucleus and the surrounding tapetum. There is thus a polarity of the cell, which presently becomes more conspicuous by the changes characteristic of synapsis within the nucleus. The chromatic material during synapsis converges to a point on the nuclear membrane against which lies a nucleole, and the entire mass of contracted chromatin is directly opposite the assemblage of starch grains in the cytoplasm adjacent to the nucleus. The nucleus, then, during synapsis presents a definite polar side with its chromatin content contracted at a point opposite the assemblage of starch grains, and an antipolar side free from chromatic substance, where also the nuclear membrane appears much heavier than in the region of the synaptic mass.

Fibers become conspicuous in the cytoplasm during synapsis, especially on the antipolar side of the nucleus, and these tend to become arranged in cone-shaped groups as the nucleus passes out of synapsis. There is at times a bipolar arrangement of the fibers, but later several well-defined poles are developed and a multipolar stage results which is similar to the multipolar spindle characteristic of spore mother-cells. The cones of the

multipolar spindle finally become grouped to form a typical broad-poled bipolar spindle. During the mitosis the starch mass lies at the side of the spindle, but as telophase comes on, it gradually moves in between the two daughter nuclei, forming an irregular thin plate between the two. This starch plate separates the two spindles of the second mitosis which lie at various angles to one another. After the four granddaughter nuclei are formed the starch becomes distributed in about equal amounts to the four cells. The polar organization of the spore mother-cell of Marsilia, conspicuous at the time of synapsis, then disappears, according to Marquette, just before the formation of the first spindle. Marquette, however, seems inclined to believe that more careful study of multipolar stages in spindle formation may establish a continuous polar organization throughout these mitoses.

These investigations of Harper and Marquette are likely to stimulate further research upon the polarity of the plant cell, and a more critical reinvestigation of favorable types where an isotropic or radial structure is believed to obtain. It may, nevertheless, be found that polarity will not depend in all cases upon the presence of permanent protoplasmic structures of sufficient size or morphological differentiation to rank as organs of the cell. There may be polarity at times without visible protoplasmic organization. It is probably very unusual for a cell to be so situated that its activities are expressed in a strictly radial fashion; there is rather certain to be an upper or lower, an inner or outer, or a one-sided relation to important environmental conditions, and these may be expected to develop metabolic centers, which, at times, may in their turn create such protoplasmic differentiation along an axis as to establish an evident polar organization of the protoplasm.

Further evidence of polar organization in plant cells is presented in the structure and development of the cilia forming organs, or blepharoplasts. Some recent research on these structures will shortly be reviewed in the NATURALIST.

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